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Mechanical and Physical Properties of SOUTHERN YELLOW PINE

Specification and Design Information and Data for the Use of Architects and Engineers

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Southern Pine Association

Mechanical and Physical Properties of Southern Yellow Pine

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Definition of Terms

THE mechanical properties of wood are those which define its strength or resistance to loads and shock. The physical properties are those which involve its structure and appearance, such as cell arrangement, fiber length, color, porosity and resistance to decay. These properties combined—strength, weight, color, hardness, ease of working, durability, shrinkage and shock resistance—determine the value of any species of wood for a specific use. Southern Yellow Pine is the wood of general construction because its mechanical properties qualify it for most structural uses and its physical properties and appearance make it available for decorative purposes. This bulletin is concerned primarily with its mechanical or strength properties. For a beam, girder or joist, the combined bending and horizontal shear resistance of Southern Yellow Pine excell that of any other commercially available species of structural wood. For a column or post, it develops high compression value parallel to the grain, combined with stiffness and resistance to impact. For flooring and interior trim, it possesses the necessary hardness, resistance to abrasion and nail holding power combined with moderate shrinkage. Southern Yellow Pine, of the coniferous woods, has the highest shock resisting ability combined with hardness. The resinous contents of the heartwood of Southern Yellow Pine is an inherent preventive against decay and makes it especially valuable for sills or transverse compression members in contact with the ground or exposed to moisture.

For sheathing or protection against the weather, the heat conductivity of Southern Yellow Pine is less than one-third that of brick or concrete and less than one-three hundreth part that of steel. For fire resistant construction, unprotected heavy timbers will resist the action of high temperature fires for a period of duration two to four times longer than that of unprotected steel and the unburned portion of the timber shows no loss in strength from the effects of fire. For a pole, vehicular or implement part, it has the requisite toughness, stiffness and resilience to resist sudden application and reversal of stress and the hardness to resist wear at joints and fittings.

COMPARISON OF SPECIES

The relative values of the mechanical and physical properties of the four species of Southern Yellow Pine is expressed in Table 1 on the basis of 100 for Longleaf Yellow Pine.

TABLE I.

*Relative Values of Four Species**

Property	Long-Leaf and Cuban	Short-Leaf	Lob-Lolly
Strength as beam or post	100	84	84
Compression flatwise	100	80	92
Shearing along grain	100	83	84
Shock resisting ability	100	90	91
Stiffness	100	82	87
Hardness	100	86	80
Weight (air dry)	100	90	90

*For a complete statement of these properties see the Southern Pine Manual of Standard Wood Construction.

It is generally impossible to definitely determine the species of manufactured Southern Yellow Pine lumber by visual inspection and it is very difficult to do so by microscopic inspection. Common to all natural products, there is a lack of uniformity and the variation of the physical properties results in an overlapping of them causing the exact point of demarcation between the species to be very indefinite. A system of grading and classifying Southern Yellow Pine without reference to species has been developed, which is based on the physical property of density which determines the strength quality.

Shrinkage

Green wood contains water within the wood substance of the cell walls and free water in the open pores. The fiber saturation point is that condition when the cell walls are still saturated with moisture but the water in the pores has evaporated and corresponds to approximately 23 per cent moisture content. When the wood dries to less than the fiber saturation point, the evaporation of the moisture is accompanied by a shrinkage of the wood substance in directions at right angles to the grain.

Heartwood shrinks less than sapwood; the larger the stick, the higher the percentage of moisture content with a proportionate decrease in shrinkage from the green condition. Tables of mechanical properties record shrinkage as the total shrinkage to oven-dry temperature and moisture content. For Southern Yellow Pine, the average total shrinkage will be 12 per cent in volume, 8 per cent tangentially to the ring growth and 6 per cent radially.

In the normal air-dry or balanced moisture condition of structural timbers at ordinary temperature and humidity, Southern Yellow Pine will eventually approximate 12 per cent moisture content, variations in the water present depending upon the size of the piece and the normal humidity condition in which the timber is placed. The shrinkage from the green condition to this normal moisture content is approximately one-half that recorded in tables of mechanical properties. Shrinkage in a radial direction is approximately one-half of that in a tangential direction and therefore edge-grain or rift-sawed material shrinks less in width than flat-grain material

At the normal moisture content of 12 per cent a 12″ edge-grain board will change approximately 1/8″ in width for each 6 per cent change in moisture content and a 12″ flat-grain board will change 7/32″ in width for each 6 per cent. change in moisture content.

Durability

Dense heart Southern Yellow Pine with an 85 per cent girth measurement heart requirement as in select structural material, or a two-thirds or more heart requirement face measurement as in merchantable material, possesses the strength, freedom from warping and checking and resistance to decay which recommend it for use in major structures without preservative treatment.

The sapwood of all species of wood is subject to rapid attack of wood destroying fungi when exposed to conditions of moisture combined with lack of ventilation. The growth of damp or dry-rot fungi is brought about by either direct contact with infected ground under favorable moisture and temperature conditions for growth, or the fungi are carried in the lumber after having been contracted in the lumber yard through improper piling of unseasoned sapwood with scant ventilation. Dry-rot fungi start to germinate in moist wood and make their way long distances into dry material.

The dense and resinous heartwood of the Southern Yellow Pine tree is highly resistant to attack. The resin content waterproofs the material and prevents the absorption of the water necessary to the growth of the fungus. In most of the cases in which serious decay has occurred on the interior of a building it developed shortly after the structure had been built and frequently in large sticks which were infected with the fungus in the lumber yard,

and which were composed chiefly of insufficiently seasoned sapwood. Frequently the error is made of completely enveloping such sticks with ornamental metal or other coverings thus eliminating all possibilities of the seasoning of the wood and creating conditions favorable to fungus growth. Such treatment can only result disastrously and should be prohibited by building laws. The dense heartwood of Southern Yellow Pine combined with its resinous content are inherent deterrents against rot.

The heartwood content of a stick is generally determined by the girth or face measurement taken as a percentage of the entire circumference or perimeter, or side of the stick as the case may be, and measured at the point where the greatest amount of sapwood occurs. The volumetric or cubical content of heartwood, in percentage of contents of the whole stick, always exceeds the girth or face measure. That is, in a square boxed-heart stick for example with the sapwood distributed on all four corners and with 85 per cent heartwood, girth measurement, the actual cubical content of heartwood is 99 per cent of the volume of the stick at the point of maximum sapwood. As the sapwood will always diminish and occasionally entirely disappear at the butt end of the tree, the actual percentages of heartwood in the volume of the stick are even greater.

Preservative Treatment *

In addition to its strength and inherent durability, the structure of Southern Yellow Pine is more adaptable to preservative treatment than any other wood used for structural purposes. When treatments are used, the preservative should penetrate all of the sapwood and as much of the heartwood as practicable. Antiseptic preservative treatment is recommended where the conditions of use are extremely conducive to rot; as in moist basements; in rooms subject to high humidity; in mills where the air is maintained moist mechanically; in exterior construction alternately wet and dry, in contact with the ground or periodically in contact with water; and where it is desired to use lower sap grades of timber. In some regions of the country, the interior woodwork and even the furniture of buildings are subject to attack by termites or flying-ants, and where such attack is common, impregnation with chemical preservative is recommended.

The wood preservatives in general use in the United States are Coal-Tar Creosote and Zinc Chloride or a combination of the two. Standard pressure treatments in which the process is so controlled as to insure a maximum penetration of the preservative are generally recommended. Where the more expensive pressure treatments cannot be obtained or are not warranted, surface applications are available which are useful in prolonging the natural life of the wood. These consist of hot and cold bath treatment, steeping in an open tank, dipping, brushing or spraying. Such surface treatments should be applied only to well seasoned material. Creosote is suitable for any of these surface treatments but zinc chloride is used only in the hot and cold bath or the steeping process.

The treatment of interior building lumber and timber may differ from the treatment suitable for exposed bridges, piles, sills or railroad ties. Timber impregnated with creosote by one of the standard pressure methods is the most satisfactory for exterior construction. For the interior of building structures, where the odor of coal-tar creosote may be objectionable or where a painted or stained finish is desired, zinc chloride treatment may be used. Other water-soluble salts which have been used to some extent in the United States are Mercuric Chloride and Sodium Fluoride. Mercuric Chloride is very effective in prolonging the life of wood; but its high cost, poisonous character and corrosive action on steel have militated against its general use. Sodium fluoride has been experimented with in this country for about ten years and the evidence thus far available would indicate that the salt gives satisfactory penetration, is toxic, and permits effective painting of wood. Its cost is somewhat greater than that of zinc chloride. For the roofs of factories maintaining high humidity or where the heat insulation of the roof is an important problem, creosoted Southern

*See specifications of the American Wood Preservers' Ass'n

Yellow Pine plank, in flat or laminated construction, provides a roof of light weight which is nonsweating and fire resistant to a high degree.*

EFFECT ON STRENGTH

The strength of Southern Yellow Pine is not impaired through treatment by standard approved processes. Tests conducted at the U. S. Forest Products Laboratory, at the Engineering Experiment Station of the University of Illinois and by the Atchison, Topeka and Santa Fé Railway Company on Southern Yellow Pine, treated by such processes, indicate that, after the material has reached its normal moisture content, its strength is equal to that of the untreated timber. Because of the waterproofing and water-resisting properties of the creosote, the strength of creosoted timber exposed to water will generally be more uniform than that of untreated material. A number of investigations into the strength of creosoted Southern Yellow Pine after periods of 30 to 40 years of exposure in active service show that it is still in good serviceable condition.**

Strength of Small Clear Specimens

The average clear wood of all species of Southern Yellow Pine has a safe bending strength or working stress in the extreme fiber of over 2,000 pounds per square inch. If in addition, the material is selected for density, that is when showing six rings of annual growth or more per inch with a minimum of one-third summerwood***, the safe working stress of the clear wood is 2,400 pounds per square inch. Southern Yellow Pine, not graded for density but containing not less than six nor more than twenty rings per inch measured over the same area designated by the density specifications of the American Society for Testing Materials, has a safe working stress of 2,150 pounds per square inch. Complete tables of all the properties of Southern Yellow Pine which make this wood valuable for so many structural and industrial uses are given in the Southern Pine Manual of Standard Wood Construction.

*See Bulletin No. 5 of this series.
**See Eng. News Record—June 2, 1921, and papers No. 1168 and 1269. Transaction—Am. Soc. Civ. Engr's.
***Specifications D 10-15 American Society for Testing Materials.

HEARTWOOD AND SAPWOOD

The sapwood of Southern Yellow Pine is just as strong as the heartwood, other things being equal. So far as the mechanical properties of timber are concerned, sapwood therefore is not a defect. The heartwood of the tree is the transformed inner sapwood which changes to heartwood accompanied by increase in resin deposits as the new sapwood forms on the outside. The strength of the timber is dependent upon the density of the growth of the wood structure. The only instance where sapwood is likely to be weaker than heartwood is found in old, overmature trees where the last new growth is porous and lightweight in character, and the density as measured by the percentage of summerwood is low even though the rings may be close.

EFFECT OF TURPENTINING

Turpentining Southern Yellow Pine trees (longleaf) does not lower the strength or decrease the resin content of the wood. This matter was fully investigated by the Forest Products Laboratory of the U. S. Forest Service and this conclusion reached after an extensive series of tests.

Strength of Structural Sizes

EFFECT OF SEASONING

The ultimate load-bearing strength of sound structural size timber is the clear wood strength reduced by the influence of defects, particularly large size knots or irregular grain in the mid-section of the piece. The elastic strength or stiffness is more dependent upon the density and physical quality of the wood fiber or wood structure than upon the knot or grain defects. In drying small size timber (joists 4″ and under in thickness), the loss of moisture results in a 20 per cent increase in strength where average defects occur. In timbers of larger size, the increased strength due to loss of moisture from seasoning is generally offset by checking around knots and along the neutral axis. In the lower grades of small dimension with large defects, checking also offsets the increase in strength due to drying.

COMMERCIAL AND USE GRADES

In general, therefore, two classes of working stresses are recommended for corresponding grades, one for *floor joists* and one for *isolated beams or girders;* for the same working stresses in smaller sizes, relatively larger defects may be permitted. The higher stress values to be employed in wood-joist construction, with the same relative limitation of defects, are suitable for dimension or heavy joist stock, 4″ and less in least dimension. The lower stress value with the same relative limitation of defects, is suitable for timbers 5″ and over in least dimension when employed as isolated beams or girders. In commercial grades, it is desirable to have a more rigid limitation of defects in the larger size stock, with equal working stress values in both large timbers and small dimension.

Southern Pine Association Structural Grades

The Southern Pine Association provides structural timber, heavy joist, and dimension grades adapted to all construction uses:

1. Select Structural Grade for heavy construction use in important engineering structures such as main stringers, girders and truss members in bridges and mill buildings.

2. General Structural Grades for all ordinary structural uses in buildings, trestles, wharves, piers and general construction, as follows:

    a. No. 1 Common, for use on the interior of buildings where not subject to high humidity and not exposed to view or where appearance is not a deciding factor, and in temporary false work;

    b. Square Edge and Sound, for exterior and interior use where appearance or use requires full sections with square corners and where the timber is highly subject to decay requiring treatment with a chemical preservative;

    c. Merchantable, for structural uses, either interior or exterior, where appearance and strength are factors and where a guaranty of durability is a requisite when used untreated.

3. In addition to the timber grades, heavy joist and dimension grades are furnished as follows:

    a. No. 1 Common for ordinary general use where members are framed to form a composite unit as in joisted-floor construction, usually covered with sheathing, flooring or ceiling on top and bottom;

    b. No. 2 Common for light load, short span work to be used similarly to the above, where deflection rather than strength is the controlling factor;

    c. No. 3 Common for a less expensive building material, commonly employed for studs and very light joists, usable by wasting 25 per cent of the length of at least one-third of the number of pieces of each item in a shipment.

Recommended Working Stresses

STRUCTURAL TIMBER

In timber constructions, warning of incipient failure occurs long before actual failure. When the design loads include allowances for impact, the recommended working stresses can very properly be increased in direct proportion to the provision for impact. Four classes of use are recognized in the following tabulations in each grade of material: *Class A* for use in exterior structures or members exposed to saturated moisture conditions such as wharves, piling and sills; *Class B* for use in exterior structures exposed to the weather but not in contact with the soil such as bridges and open sheds; *Class C* for use in interior dry structures such as enclosed buildings, roofs and roof trusses; and *Class D* for use in temporary false work, either interior or exterior.

TABLE II.

Recommended Design Stresses

(*Lbs. per sq. in.*)

SELECT STRUCTURAL GRADE, DENSE*

	Class A	Class B	Class C	Class D
Bending, extreme fiber	1200	1500	1800	-
Direct tension (net area)	1200	1500	1800	-
Compression (short columns)	1000	1200	1350	-
Compression (long columns)	Reduce direct compression by product of (C/75) x l/d.***			
Compression (flatwise)	250	300	350	-
Longitudinal shear (uniform load)	100	125	150	-
Longitudinal shear (concentrations)**	150	175	200	-
Shear with grain (details)	150	150	150	-
Design weight per cu. ft.	48 lbs.	48 lbs.	42 lbs.	
Modulus of elasticity	1,600,000 lbs. sq. in.			

TABLE III.

Recommended Design Stresses

(*Lbs. per sq. in.*)

GENERAL STRUCTURAL GRADES,
*Graded for Density**

	Class A	Class B	Class C	Class D
Bending, extreme fiber	1100	1400	1600	2000
Direct tension (net area)	1100	1400	1600	2000
Compression (short columns)	900	1100	1200	1600
Compression (long columns)	Reduce direct compression by product of (C/75) x l/d.***			
Compression (flatwise)	250	300	350	500
Longitudinal shear (uniform load)	100	125	150	275
Longitudinal shear (concentrations)**	150	175	200	275
Shear with grain (details)	150	150	150	275
Design weight per cu. ft.	48 lbs.	48 lbs.	42 lbs.	48 lbs.
Modulus of elasticity	1,600,000 lbs. sq. in.			

*A. S. T. M. Specifications for Density.

**Concentration within two beam depths of end support.

***C—value for Compression (short columns).

TABLE IV.

Recommended Design Stresses

(*Lbs. per sq. in.*)

GENERAL STRUCTURAL GRADES,
(*Not graded for density or ring count*)

	Class A	Class B	Class C	Class D
Bending, extreme fiber	900	1100	1200	1800
Direct tension (net area)	900	1100	1200	1800
Compression (short columns)	800	900	1000	1400
Compression (long columns)	Reduce direct compression by product of (C/75) x l/d.***			
Compression (flatwise)	250	300	350	500
Longitudinal shear (uniform load)	100	110	125	200
Shear with grain (details)	100	110	125	200
Design weight per cu. ft.	48 lbs.	42 lbs.	36 lbs.	48 lbs.
Modulus of elasticity	1,600,000 lbs. sq. in.			

HEAVY JOISTS AND DIMENSION

For house framing with interior plastered ceilings, the depth of floor beams is usually determined by safe limits of deflection. This type of construction occurs largely in residence buildings for which building code requirements exceed the actual live loads that are likely to obtain. Designs based on the following stresses will result in satisfactory construction. The better grade material will be utilized especially in offices, warehouses, store and mercantile buildings of wood joisted construction.

TABLE V.

Recommended Design Stresses

SELECTED NO. 1 COMMON DIMENSION

Bending, extreme fiber	1800	lbs. sq. in.
Compression (flatwise)	350	" " "
Shear with grain	150	" " "
Modulus of elasticity	1,600,000	" " "
Design weight per cu. ft.	42	"

TABLE VI.

Recommended Design Stresses

COMMON DIMENSION

Bending, extreme fiber	1200	lbs. sq. in.
Compression (flatwise)	350	" " "
Shear with grain	125	" " "
Modulus of elasticity	1,600,000	" " "
Design weight per cu. ft.	36	"

In small dwellings, particularly of all frame construction, where 2″ dimension stock is commonly used for floor joists, studs and rafters, the element of bending strength is not the determining factor. The extreme fiber stress in members of this type of construction, proportioned for stiffness, will rarely, if ever, exceed 1,000 pounds per square inch.

Special Uses

For intermittent, indefinite loads of short duration such as occur in transmission line towers, the specified working stresses for structural Southern Yellow Pine can be safely increased 50 per cent., that is for dense material, bending in extreme fiber can be computed at 3,000 lbs. per square inch and for sound material (not graded for density) at 2,400 per square inch.

The engineering and architectural service divisions of the Southern Pine Association will gladly co-operate with engineers and architects in the solution of any special problems involving the use of Southern Yellow Pine.*

*For detail use recommendations and tables of safe loads, see Bulletin No. 6 of this series.

Trade-Marked

Grade-Marked

Southern Yellow Pine